



# Selective Injection of Magnetic Domain Walls in Permalloy nanostripes.

Johanna Akerman<sup>1</sup>, Manuel Muñoz<sup>2</sup>, Marco Maicas<sup>1</sup>, José L. Prieto<sup>1</sup>.

1. Instituto de Sistemas Optoelectrónicos y Microtecnología, Universidad Politécnica de Madrid, Madrid, Spain.

2. IMM-Instituto de Microelectrónica de Madrid.

# Motivation

## Future Magnetic Memory Devices

### Exquisite control

Reliable Injection  
Controlled Pinning  
Defined Depinning Process

### Different types of DWs:

- Notch dimensions (Zhu APL 2012, Faulkner JAP 2004)
- Stripe thickness (Bogart PRB 2009)
- Stochastic behaviour (Boklage APL 2013, Im PRL 2009, Akerman PRB 2010)

Which type of DW will likely pin??



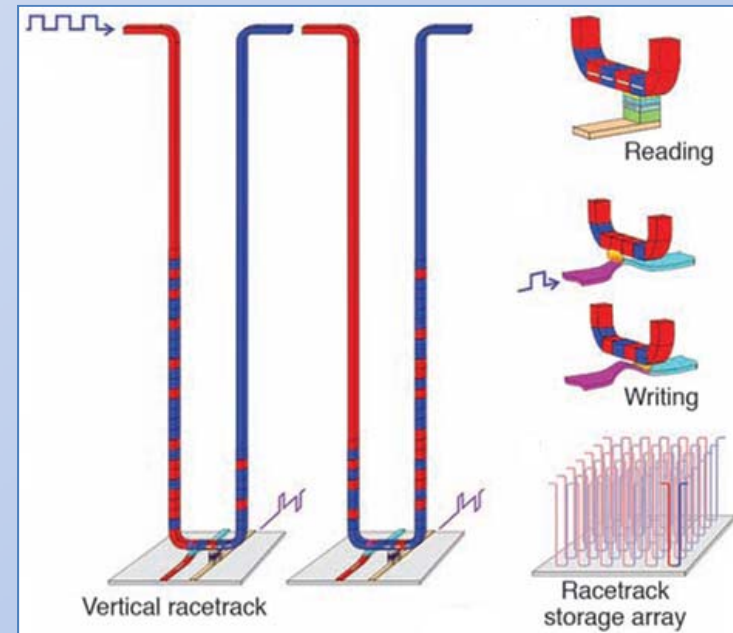
CI Depinning: Joule Heating /STT

- Spatial Distribution of J and magnetization around the notch.

We explore the conditions of DW injection

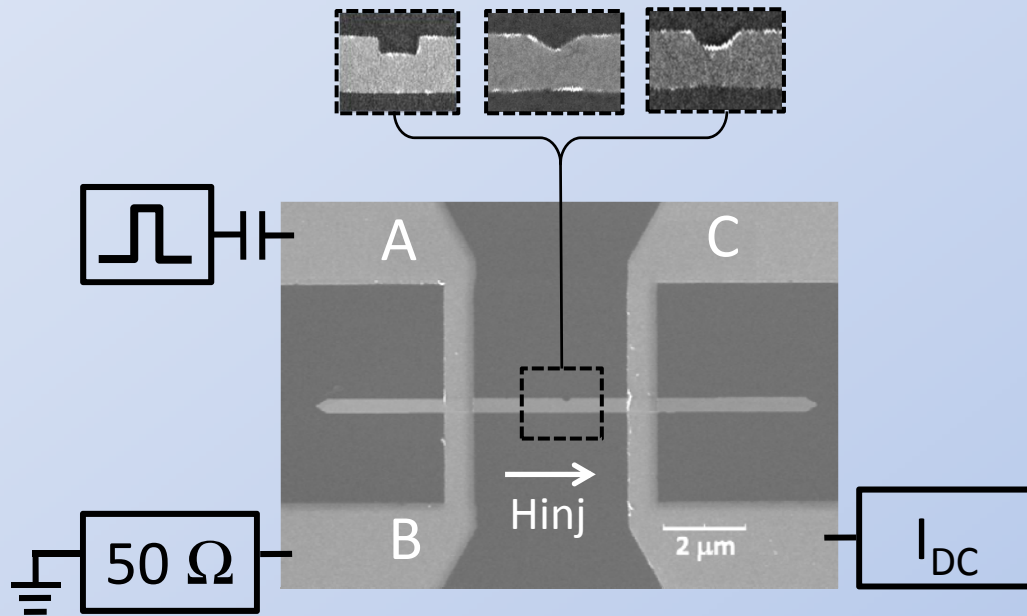


Selective Pinning of different types of DWs



S.S.P. Parkin *et al.* Science 320, 190 (2008)

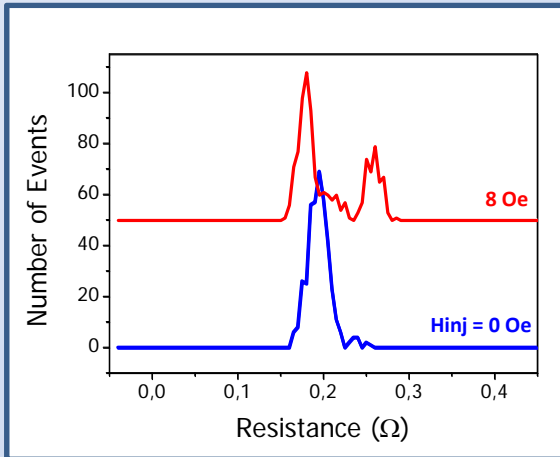
# Device Fabrication & Experimental Setup



- E-beam Lithography  
Sputtering  
Lift Off
- Ta/Py(10nm)/Ta/Pt  
300 nm wide
- 3 Notch Shapes:  
300 nm  
100 nm

- V pulse :  
1,4V      10ns
- $H_{prop} \approx 2\ Oe$       Good!!

## Quasistatic Pinning

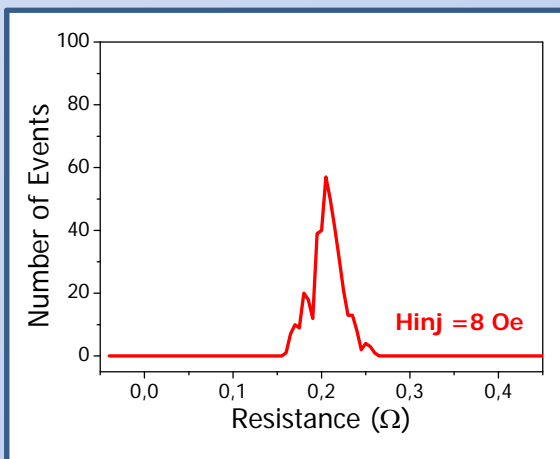


- $H_{inj} = 0 \text{ Oe} < H_{prop}$

**1 type Unpinned DWs !!!** (Prieto PRB 2011, Muñoz Nat Comm 2011)

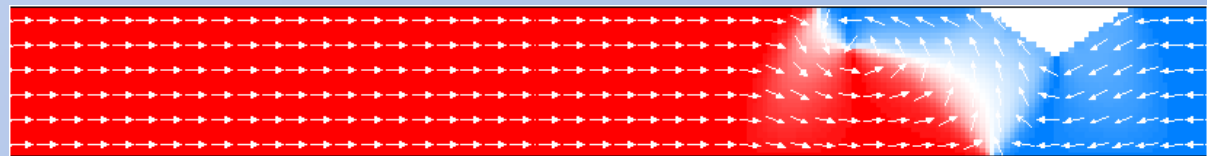


## Dynamic Pinning

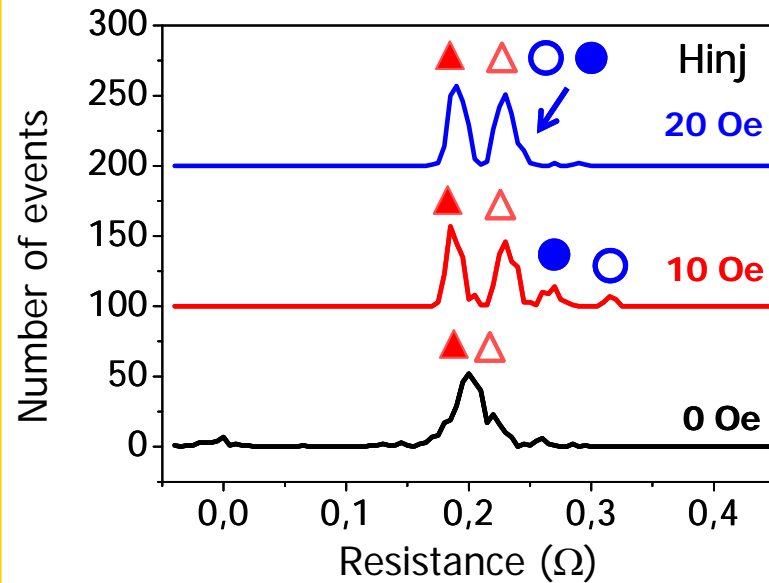
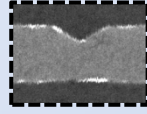


- $H_{inj} = 8 \text{ Oe} > H_{prop}$

**1 Type Pinned DWs !!!**



# Results



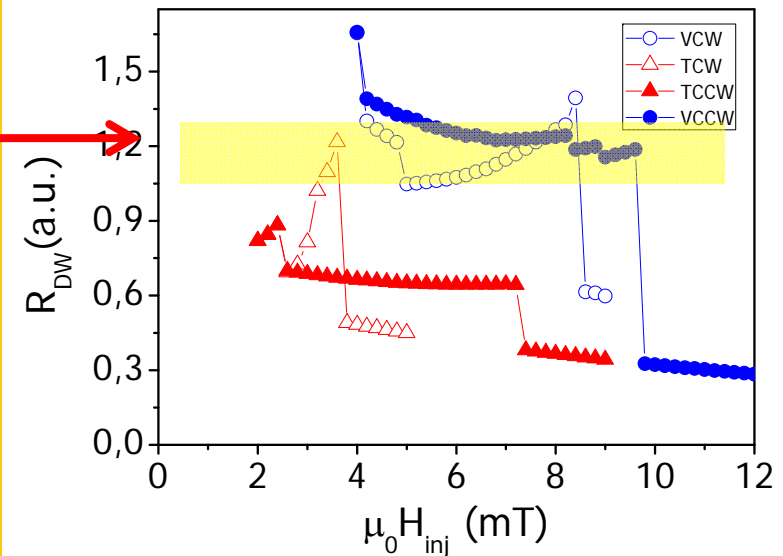
- $H_{inj} = 0$  Oe  
1 peak at  $0.20 \Omega$  Unpinned TWs
- $H_{inj} = 10$  Oe  $\approx H_{walker}$ 
  - ▲  $0.19 \Omega$
  - △  $0.22 \Omega$
  - $0.27 \Omega$
  - $0.32 \Omega$
- $H_{inj} = 20$  Oe  
Only 2 peaks??!!

## Micromagnetic Simulations: OOMMF

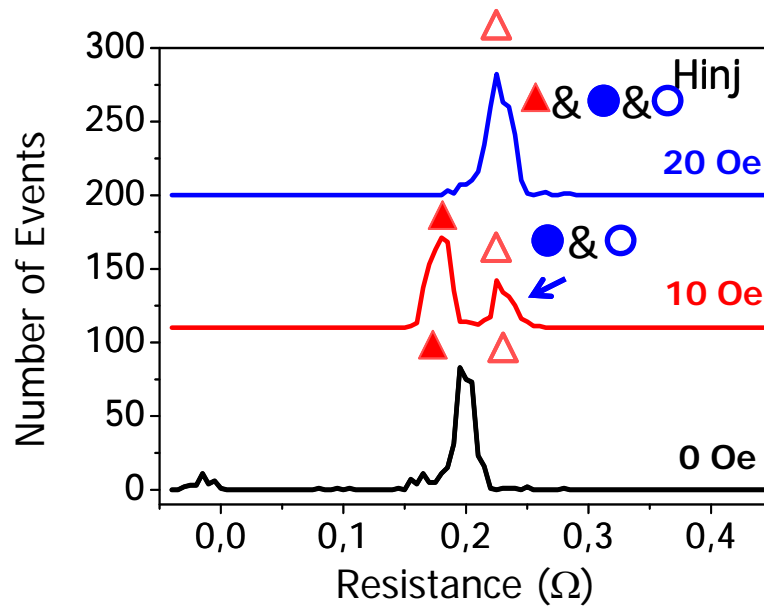
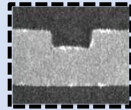
- $\alpha = 0.01$
- $H_{\perp} = 5.5$  mT
- VCCW  $\rightarrow$  TCCW

Similar AMR Value

Above  $H_{walker}$  + No depinning events  
All DWs types should be there!!

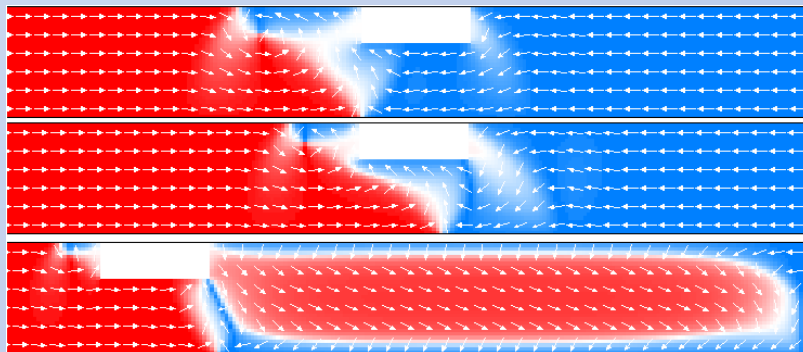


# Results

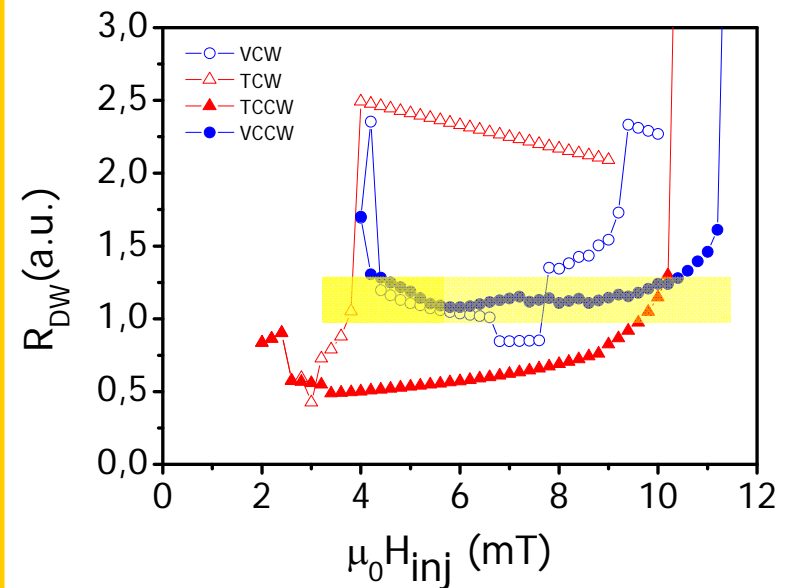


## Micromagnetic Simulations: OOMMF

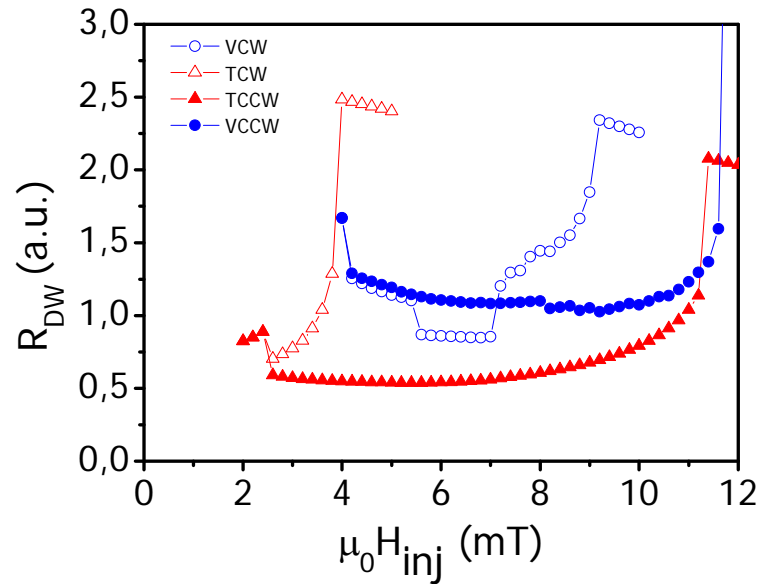
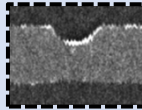
- VCCW  $\rightarrow$  TCCW. 360°



- $H_{inj} = 0$  Oe  
1 peak at 0.20  $\Omega$  Unpinned TWs
- $H_{inj} = 10$  Oe  
1<sup>st</sup> peak at 0.185  $\Omega$   $\blacktriangle$   
2<sup>nd</sup> peak at  $\left\{ \begin{array}{l} 0.220 \Omega \text{ } \triangle \\ 0.230 \Omega \text{ } \bullet \circ \end{array} \right.$
- $H_{inj} = 20$  Oe  
1 peak

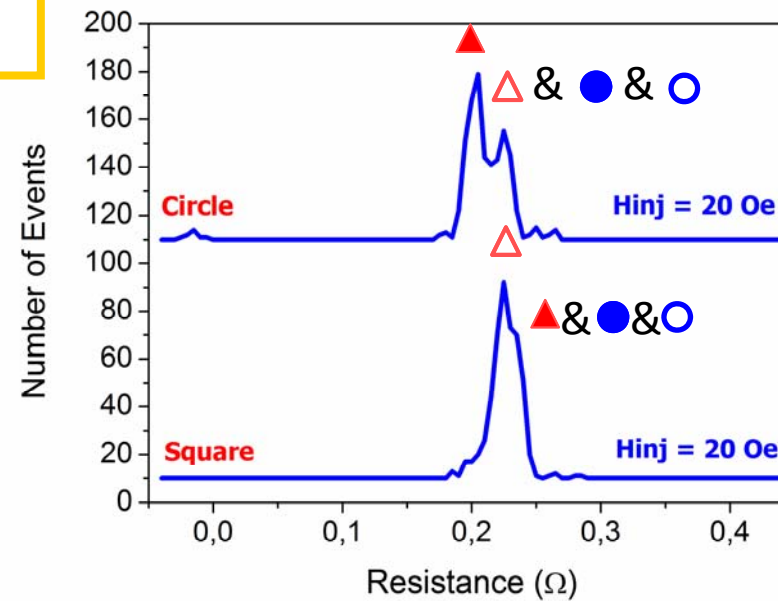


# Notch



## Micromagnetic Simulations: Oommf

- Similar to Square notch.
- TCCW smaller dependency with  $H_{inj}$   
0,19Ω at  $H_{inj} = 20$  Oe

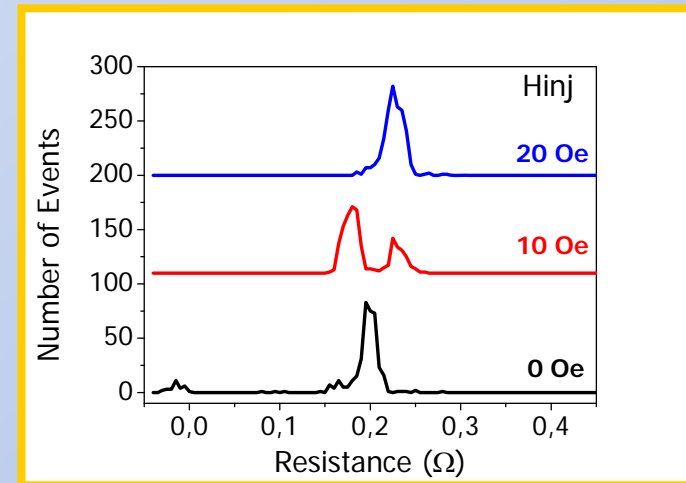


# Conclusions

- We have studied the conditions of DW injections that allow selective pinning of different types of DWs.

- $H_{inj} = 0 \text{ Oe}$       TCCW + TCW

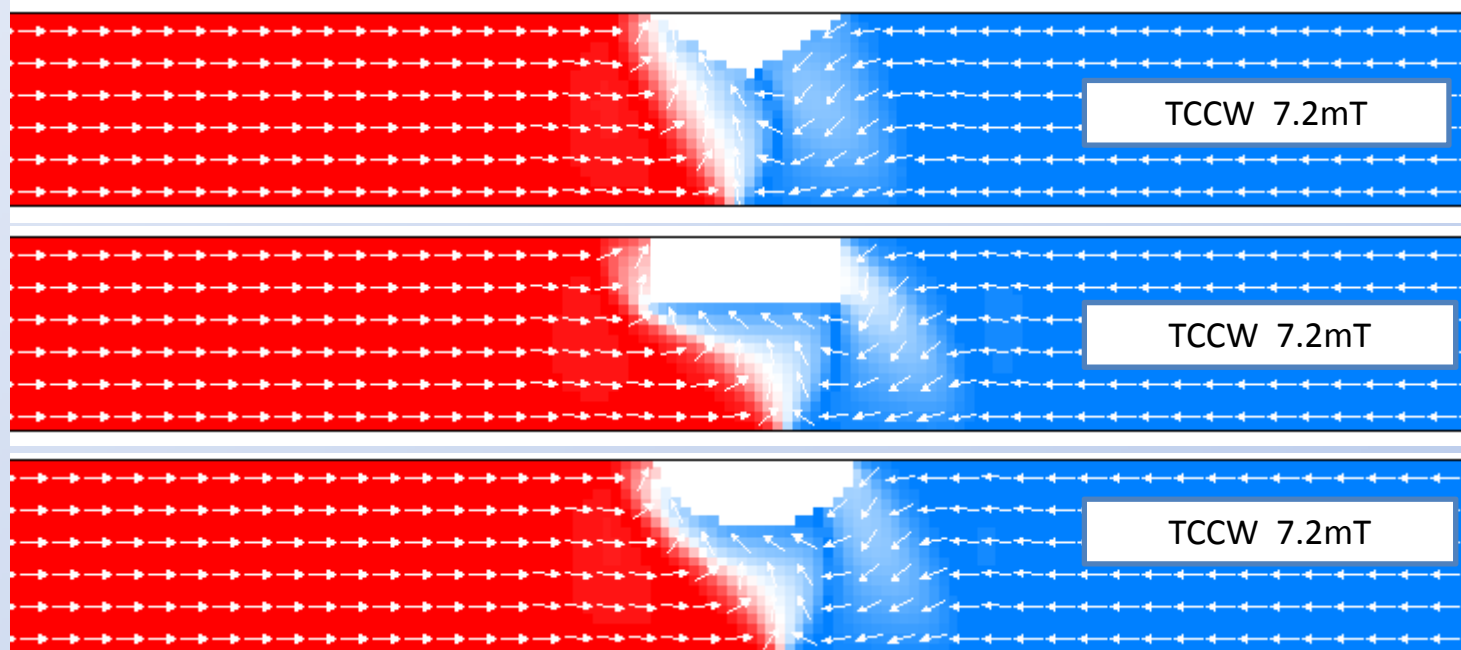
$H_{inj} > H_{walker}$  + No depinning events

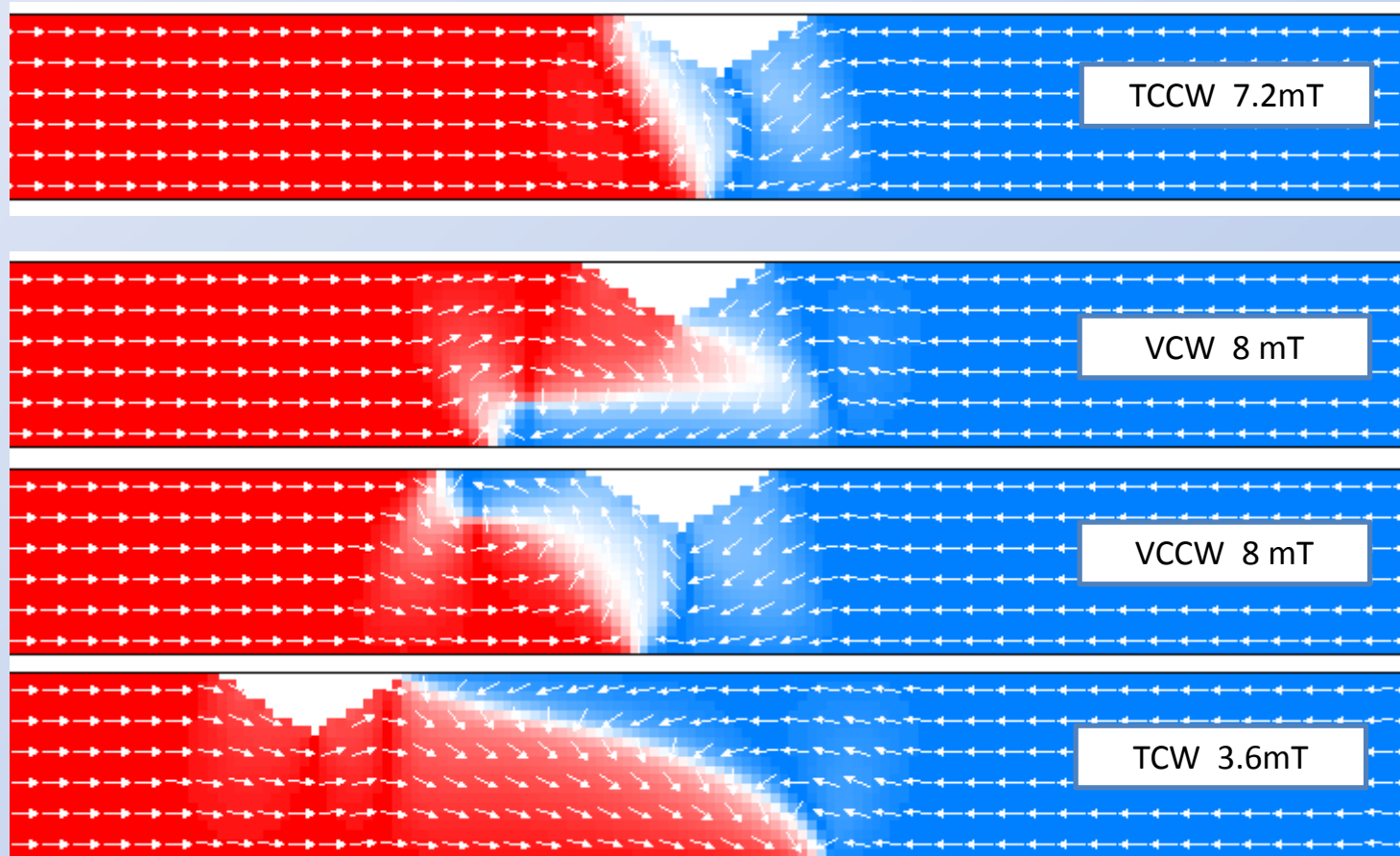


- The apparent absence of some DWs at high or moderate  $H_{inj}$  indicates that AMRs of different DWs gets similar!
- Changing the shape of the notch alters slightly the notch pattern.
- Careful should be taken when associating a value of AMR to a type of DW!!!



Thank you for your attention





Esto explica los dos picos del triangulo a  $H_{inj}=200e$ .

Es el valor de la ARM de la pared justo antes de depinarse. Fact 1

Todo cuadraría si no fuera porque la TCW va a su puta bola básicamente y no puedes decir a campo “a campo alto” para esto porque en teoría a campo alto debería haberse ido.

Si te fijas en la tesis de Hayashi, en la imagen de MFM la TC (pag 57) aparece pineada en el centro del notch y no a su derecha como en mis simulaciones. Esto explica que se necesite mas campo para depinearla, en la realidad que en la simulaciones. ¿Porque pasa esto? Se podría argumentar esto con el Stochastic pinning que a campo alto la pared esta mas distorcionada y se pinea mas? Por eso cuando debería desanclarse sigue pineada, que en la simulaciones no se ve pero en la realidad existe y esta medido. Fact 3

